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SUBSTITUTE SPECIFICATION

COLOR AND INTENSITY MEASURING MODULE FOR TEST OF LIGHT EMITTING COMPONENTS BY AUTOMATED TEST EQUIPMENT

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority from U.S. Provisional Application No. 60/450,033 filed February 26, 2003.

FIELD OF THE INVENTION

The present invention relates to the optical testing of light-emitting components and, more particularly, to a test module which may be used in conjunction with conventional automatic test equipment to optically test light-emitting components.

BACKGROUND OF THE INVENTION

Electronic assemblies are built with a multitude of light-emitting components, primarily light emitting diodes (LED's), to indicate functions, or faults occurring on the assemblies. In addition to light, information on the nature of the operations of faults on these assemblies is conveyed by the color emitted by the devices. Light emitting diodes are available in colors covering the entire visible spectrum as well as white.

Various methods have been implemented to verify the correct operation of these light-emitting components, from test sequences where human verification is used, to photo detectors employed to perform the tests automatically.

Human verification is slow and unreliable. While photodetectors can easily verify that light is present, validation of the correct color has become extremely important. Photodetectors employing narrow bandpass color filters have been employed to test for the proper emitted wavelength, with limited success, since variations in output levels of the photodetector

cannot discriminate intensity from colors approaching the edge of the passband. This becomes critical in the very narrow color bands in the visible spectrum.

In addition, these implementations require that each photodetector be customized for the particular wavelength of the light-emitting component under test, adding lead time and expense to their use. Current photodetector solutions are available in various configurations, some having the detector itself mounted near the light-emitting component, where others use fiber optic cable to collect the light and present it to a remotely mounted photodetector. Consequently, a need exists for a test module for automated test equipment to test light emitting components which addresses the problems associated with prior test apparatus.

SUMMARY OF THE INVENTION

The present invention provides a test module and a method to accurately test the operation of light-emitting devices described, and provides parametric values for color and luminous intensity, which can be compared automatically to expected values. The test module contains a sensor or plurality of sensors, each of which contains three photodetectors. The three photodetectors are individually filtered to pass the red, green, and blue portions of the visible spectrum.

When the light from the photo-emitter to be tested is presented to this three-color sensor, the individual outputs of the detectors divide the light into levels of red, green, or blue component. After signal conditioning the individual color components are converted to digital values, then presented to a preprogrammed microcontroller.

The microcontroller is programmed to use the combination of all of the color component values to determine the luminous intensity and the ratios of the individual color values to

algorithmically match the monochromatic input color to wavelength, based on CIE color matching values. Additional tests are made to determine if the color components are all above a preset threshold, indicating the presence of a white color source.

The microcontroller presents the wavelength and intensity values to digital to analog converters, which produce an analog wavelength value linearly scaled to the visible spectrum, 380 nanometers through 700 nanometers, and an intensity output linearly representing luminous intensity. In the case of white, a voltage value above the visible values will be output to indicate the presence of white light. Light levels below a preset low limit will force both the color and intensity outputs to zero volts.

These voltage values are read by the automatic test system and compared against expected values to determine if the correct light-emitting component has been installed and is operating correctly in the assembly.

The test module described provides a low cost and easily implemented method of performing parametric color tests on light-emitting devices. It requires no calibration or setup once installed in the test apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic perspective view of the light testing module of the present invention;

FIG. 2 is a detailed view of the test probe of the module of FIG. 1;

FIG. 3 is a schematic view of the test module of FIG. 1;

FIG. 4 is a CIE color matching chart; and

FIG. 5 is a CIE color ratio matching chart.

DETAILED DESCRIPTION

Referring to Figure 1, the light testing module 10 of the present invention consists of an assembly of sensors 12 to which the light from the emitter under test is presented. In the implementation shown, the light is piped to the sensors using fiber optic cable(s) 14 connecting to the sensors using plastic fiber connector(s) 16. The sensors are located under a light shield 18 to prevent entrance of ambient light. Electronics 20 on the assembly condition the sensor signals, process the red, green, and blue components of the light, and produce wavelength and intensity outputs. Additional electronics 22 is provided to select one of n sensors on the module corresponding to the light-emitter currently under test. A connector 24 is provided for wiring the test module to automatic test apparatus to provide power for operation, one of n sensor selection, and output values. All of the components of the test module 10 can be mounted on a printed circuit board 26 or other suitable device.

Figure 2 is a detail view of the termination of the fiber optic cable 14 at the light emitting device 28 to be tested. An end of the flexible plastic optical fiber 14 is encased in a rigid tube 30 to provide pointing accuracy to the device under test 28 mounted on a printed circuit board 32. The fiber optic cable is cut flush with the end of the tube 30, and held in position using adhesive backed heat shrink tubing to hold the fiber in position in the tube. The supporting tube is mounted rigidly, preferably by an adhesive 34, to a plate 36 to provide centering of the assembly at the optical center of the device under test 28, as well as providing a minimal spacing from the device to prevent damage to the fiber or device under test. A connector 38 is positioned on an end of the tube 30. The numerical aperture (acceptance angle) of the optical fiber is

such that a portion of the emitted light is collected by the fiber, dependent on the viewing angle of the light-emitting device under test, and the spacing of the fiber from the light-emitting device. Since color determination is accomplished using ratios of the primary colors, the percentage of the total light collected is not critical to the measurement.

While this particular implementation uses fiber optics to couple the light, alternatively, similar modules could be implemented where the light sensor is mounted at the light-emitter under test, and electrically connected to the electronics on the test module for processing.

Referring to the schematic in Figure 3, the individual color photodiodes 40a, 40b and 40c which comprise the sensors 42 are amplified 44 then selected by an analog multiplexer 46. The analog signals are then digitized by the analog to digital converter 48. Two digital to analog converters 50 and 52 convert the calculated values of wavelength and intensity from the microprocessor 54 to analog values which can be read back to the automatic test apparatus 56 for pass/fail comparison.

The preprogrammed microprocessor 54 performs calculations to determine intensity, and wavelength of the incoming light. Luminous intensity is calculated as a function of the total energy captured by the red, green and blue photodiodes, factored by the preconditioning and equalization which has been done. First, tests are run to determine if sufficient light intensity is present to process. Below the present limit, the processing will terminate, and zero volts programmed to both the intensity and wavelength analog to digital converters to indicate no useable signal is present.

If the low limit tests pass, tests are then performed to check for equality of all three color components for white light determination. If the red, green, and blue components are equal

within a preset percentage, color calculations are skipped, and the wavelength output value is set to a predetermined output voltage level which indicates a white source is present.

If the test indicates the light is monochromatic, the color processing is run, first determining the order of the color by decreasing magnitude. Based on this order, sets of algorithms to calculate the wavelength are called. These algorithms calculate the wavelength by mathematical operations which convert the red, green, and blue magnitudes into wavelength based on the CIE color conversion values for human perception of color, as shown in the graph of Figure 4.

The chart shown in Figure 5, shows the ratio of the red, green and blue color mix throughout the visible range. These ratios alternatively are calculated based on the levels present at the sensors, and used as an index into lookup tables contained in the microprocessor memory. These tables correlate the ratios of red, green, and blue directly into the equivalent wavelength in nanometers. The wavelength is converted to a scaled voltage, which is then output by the digital to analog converter.

Once the wavelength is determined, a digital value is output to the digital to analog converter, which represents a direct voltage match to the calculated wavelength. For instance, 550 nanometers would output 550 milivolts, or a multiple of that value, to make the voltage more readable by the automatic test system.

Additional inputs 58 to the module are provided for digital selection of the sensor to be addressed, as well as power to run the module.

The sensor or sensors are capable of detecting the content of red, green, and blue or the complements cyan, yellow and magenta, to allow for the weighing of the individual colors to determine the wavelength of an incoming beam. The sensor can be

a monolithic tricolor sensor, or individual filtered photodiode sensors with the optics to disperse the light equally across the three sensors. The colors are not limited to three and can be any number or color, required to effectively differentiate the incoming wavelength. The test module has the capability of selecting the individual sensor, the processing capability to calculate the wavelength from the levels of the sensed colors, and an output interface to present the wavelength data to the automatic test equipment in a digital or analog form.

In one embodiment, the multi-color sensor and amplification or a plurality of sensors and amplifiers are mounted remotely, at the light emitting-device under test, and electrically connected to the remainder of the electronic processing. Alternatively, the multi-color sensor or a plurality of sensors can be mounted with the processing circuitry, for use with fiber optic cables used to collect the light from the light-emitting device under test and transmit the light signals to the sensors. The test module uses a predefined set of color ratios based on standard color matching tables, modified by sensor response, to determine wavelength by comparing the color ratios of the incoming light irrespective of the absolute values. The test module which provides a calculated wavelength output, based on the proportion of the content of colors detected in the light output of a monochromatic emitting device.

The test module also determines a white source from a light-emitting device when all of the color sensor levels contribute equally to total input. The test module converts the input light to an analog signal scaled directly from nanometers to milivolts or a multiple thereof throughout the visible spectrum of 380nm to 700nm, and uses a unique voltage level in excess of the range of visible spectrum converted voltages to denote the detection of a white source.